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LHC Interaction Region Quadrupole Interconnect Weld Joint Technical Note

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LHC Interaction Region Quadrupole Interconnect
Weld Joint Technical Note

Table of Contents

Chapter 1

LHC Interaction Region Quadrupole Interconnect Weld Joint Technical Note

1.0 Introduction

This document constitutes the technical note for the LHC interaction region quadrupole interconnects being fabricated at Fermilab. It addresses the adequacy of the weld joint design for installation at CERN.

The magnet, piping and vacuum vessels will not be ASME Boiler and Pressure Vessel Code stamped vessels (hereinafter referred to as "the Code"). We do meet the Fermilab requirement to apply the design rules of the Code such that the intent of the Code is realized, i.e. that the geometry of all welds are consistent with the Code, that allowable stresses are met, etc. Fermilab manufacturing practices do not meet all of the Code requirements, most notably the continuous monitoring of all production processes, radiography of welds, etc. For that reason, Fermilab procedures require that allowable stresses be de-rated to 80% of their Code values. For the design and analysis of internal piping, we have applied the rules and practices outlined in ASME Code for Pressure Piping, B31.3, "Chemical Plant and Petroleum Refinery Piping".

1.1 Summary of results

It will be shown that the design of the weld joints in the interconnects are consistent with the operating requirements at MTF. Chapter 2 will address the weld joint design in detail and will document the stress levels in the weld at the specified design pressure.

We believe the designs of the interconnect weld joints documented in this note are adequate to ensure that their operation represents no hazard to personnel or to any of the external systems to which they will be connected.

Chapter 2

LHC Interaction Region Quadrupole Interconnect Weld Joint Design

2.0 Introduction

The interconnect is the region between magnets and also between the magnet and the feedbox. The purpose is to transport cryogens, electrical wiring and insulating vacuum from the feedbox to the magnet. There are nine total pipes which make up the interconnect consisting of six unique weld joint designs. The pipe descriptions and a summary of their operating parameters are shown in table 2.0.1.

Table 2.0.1. Interconnect pipe operating parameters

Parameter	HX Outer Shell, L	Cooldown Line, LD1	50-70 K Shield, EE and FF	Pumping Line, XBt	Cold Mass, M1, M2, and M4	HX Inner, XB
Internal Media	Lhe	Lhe	Ghe	Lhe	Lhe	Lhe
External Media	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Lhe
Operating pressure	1.3 bar	1.3 bar	19.5 bar	1.3 bar	1.3 bar	Vacuum
Internal Design Pressure	20.0 bar	20.0 bar	22.0 bar	20.0 bar	20.0 bar	4 bar
External Design Pressure	1 bar	1 bar	1 bar	1 bar	1 bar	300 bar
Temperature Range	1.9 - 300 K	1.9 - 300 K	50 - 300 K	1.9 - 300 K	1.9 - 300 K	1.9 - 300 K

2.1 Weld Joint Detail

All of the weld joints described in this note are socket joints with a fillet weld for closure. A typical weld joint detail can be seen in Figure 2.1.1.

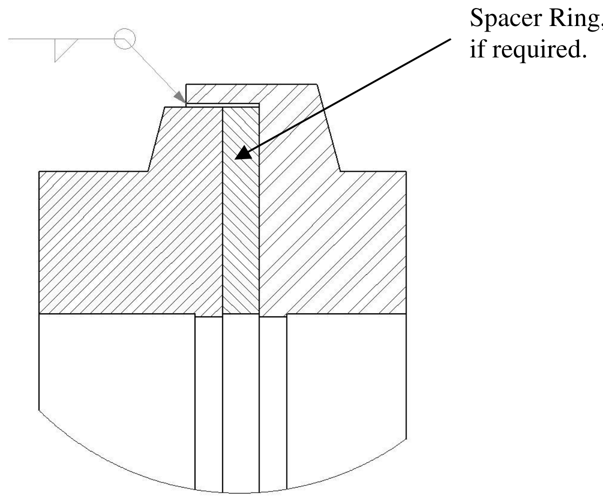

Figure 2.1.1. Typical weld joint detail.

2.2 Weld Joint Stress Calculations

The welds between the flanges of the interconnect pipes are full fillet welds. The maximum load on the weld is a combined load due to the internal pressure and the attached bellows. The force due to internal pressure is equal to the cross sectional area in the pipe multiplied by the design pressure. The force due to the bellows is equal to the spring constant multiplied by the travel of the bellows. The stress on the weld is given by

$$\tau_w = \frac{f_a}{(l)(t_w)}$$

where: τ_w = shear stress in the weld

f_a = axial force from pressure and bellows [lb]

l = linear length of weld [inches]

t_w = weld equivalent thickness [inches]

Table 2.2.1 shows the parameters for each connection with the combined loading and calculated stresses.

Table 2.2.1. Calculated stresses in interconnect weld joints.						
Parameter	*XB*	*L*	*EE & FF*	*LD1*	*XBt*	*M1, M2, M4*
Design Pressure [psi]	300	300	325	300	60	300
Flange OD [mm]	114	201	75	75	134	134
Flange edge thickness [mm]	2.125	3.125	2.125	2.125	2.5	2.25
Bellows spring rate [lb/in]	N/A	2232	977	977	301	0
Bellows travel (worst case in tension) [in] *	N/A	0.75	0.75	0.75	0.75	0
Axial force on weld due to bellows [lb]	0	1674	732.75	732.75	225.75	0
Axial force on weld due to internal pressure [lb]	4746	14755	2226	2054	1312	6558
Total axial force on weld, fa [lb]	4746	16429	2958	2787	1537	6558
Linear length of weld, l [in]	14.10	24.86	9.28	9.28	16.57	16.57
Weld equivilant thickness, tw [in]	0.059	0.087	0.059	0.059	0.070	0.063
Stress [psi]	**5690**	**7596**	**5391**	**5079**	**1333**	**6317**

*: The bellows protectors must be installed prior to any pressurization of the bellows.

The allowable stress given by UW-15 of the Code for 304 stainless steel is:

$$(20{,}000 \text{ psi})(0.8)(0.49) = 7{,}840 \text{ psi}$$

All of the welds in the interconnect are below the allowable stress given by the Code. All of the requirements of the Code have been satisfied.

2.3 Summary

The interconnect weld joint designs satisfy all the requirements of the ASME Code. It was shown that the stress in each weld is below that allowed by the Code.